Marine Stewardship Council Accreditation of North Minch *Nephrops* trawl fishery

Year 1 Scientific Report

December 2009

Bycatch in the North Minch *Nephrops* Trawl Fishery

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Year 1 Scientific Report to the Marine Stewardship Council

In relation to

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Introduction

The Scottish fisheries for the Norway lobster, *Nephrops norvegicus* are extremely valuable, with landings of this species worth an estimated £104 million in 2007 (Keltz and Bailey, 2009). The fisheries in Scotland are effectively divided between a mixed fishery in the North sea which captures and lands *Nephrops* and whitefish, and a single-species *Nephrops* fishery in the West of Scotland. It is the *Nephrops* fishery in the North Minch area in the West of Scotland which is the focus of this report.

The North Minch fisheries are managed under ICES Area VIa and Functional Unit (FU) 11 (Figure 1). Many of the Scottish vessels working in this area are based in the port of Stornoway on the Isle of Lewis, and include dredging, trawling and creeling vessels which predominantly target *Nephrops* and other shellfish in the north and south Minches to the east of the Outer Hebrides. *Nephrops* was the most valuable landed species in Stornoway in 2008, with a landings value of approximately £2.62 million (the total value of all landed species was approximately £2.75 million). Commercial whitefish stocks in Area VIa as a whole are believed to be at extremely low levels (Keltz and Bailey, 2009), and unlike mixed-fishery fleets in other areas, whitefish have a relatively low value to the fishermen working out of Stornoway and little bycatch is landed.

(a) (b)

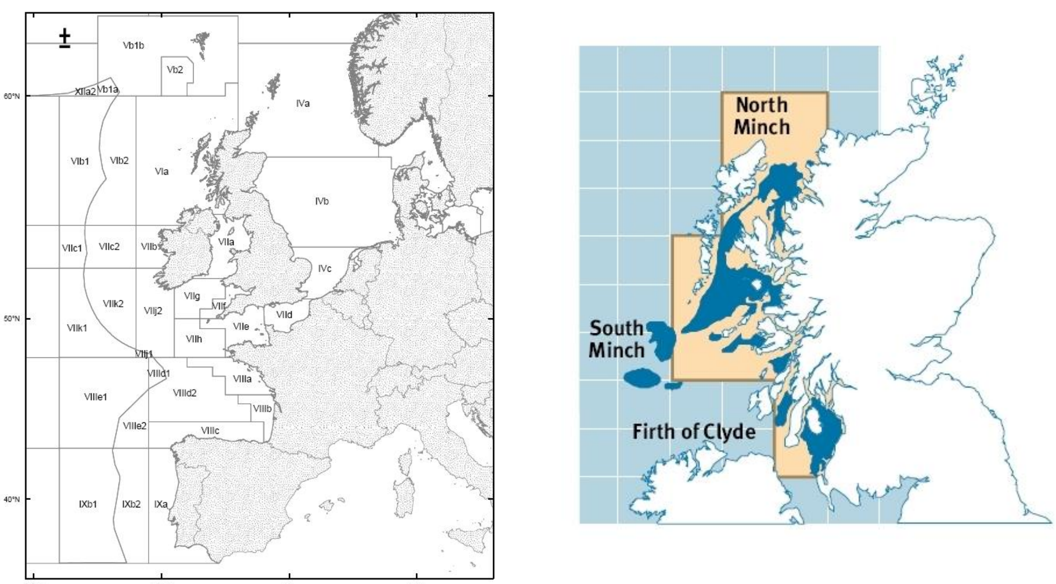


Figure 1: Map showing (a) ICES Areas in the west of Europe and (b) Functional Units within ICES division VIa (adapted from Keltz and Bailey, 2009).

However, due to the extreme decline of commercial fish stocks in the West of Scotland, fisheries managers are increasingly concerned about the impact of commercial fishing practice where species belonging to depleted stocks are captured as bycatch. This is particularly true of single-species *Nephrops* trawl fisheries which (because they are only targeting *Nephrops*, not whitefish) are permitted to fish using smaller-mesh gear compared to mixed-fisheries. Current management measures implemented in the single-species *Nephrops* fisheries in the west of Scotland include a minimum landing size (MLS) of 20mm carapace length (ICES, 2005) and minimum codend mesh sizes of 70mm for single-rig and 80mm for twin-rig gear (Bergmann *et al.,* 2002), whereas a minimum codend mesh size of 120 mm is enforced in mixed fisheries (ICES, 2005). Consequently, the capture of undersize roundfish is a much greater problem in the single-species fisheries as there is less opportunity for the fish to escape the gear (e.g. Briggs, 1985, Stratoudakis *et al.,* 2001, Catchpole *et al.*, 2007, Catchpole and Revill, 2007).

Twelve of the trawl vessels operating out of Stornoway currently supply N*ephrops* to Young's Seafood Ltd. either as whole animals (largely for export) or 'tails' (largely for the domestic market), and are equipped with the 'YoungsTrace' system, which has been designed to track each individual catch from the fishing vessel through the landing, processing and transportation stages and to the final consumer. It is this particular sector of the fleet that will be examined through the current project, and the specifications of these vessels are provided in table 1. Thanks to the use of the 'YoungsTrace' traceability system and the results of an earlier pilot study carried out by Milligan *et al.* during 2007-2008, the trawlers using the system to target *Nephrops* in the north Minch were awarded Marine Stewardship Council (MSC) accreditation on 14th April 2009, the requirements of which define several of the major aims of this work.

Table 1: List of trawler vessels supplying *Nephrops* to Young's Seafood in 2008

Vessel Name	Year Built	Registration	Length (m)	GRT	Power (KW)	Gear Type	Codend mesh size (mm)	SMP size (mm)
Comrade	1963	SY337	16.65	23.16	355	Single rig	70	90
Flowing Stream	1969	SY822	16.68	24.81	119	Single rig	70	90
Kaylana	1978	SY21	17	24.9	284	Twin rig	95	90
Laura Ann	1971	SY586	16.42	24.18	164	Single rig	70	90
Northern Star	1968	SY11	16.46	24.05	149	Single rig	70	90
Ocean Spirit	1979	SY21	13.1	23.6	134	Single rig	70	90
Sharon Rose*	1974	SY190	16.98	27.42	244	Twin rig	95	90
Wavecrest	1968	SY337	16.34	23.15	134	Single rig	70	90
Shiegra	1971	SY7	17.03	24.95	131	Single rig	70	90
True Vine	1974	KY7	15.24	23.43	171	Single rig	70	90
Lead Us	1972	SY144	15.51	24.37	274	Single rig	70	90
Faithful Friend	1970	FR615	18.26	unknown	235	Single rig	70	90

* Sold in 2009 and replaced by the *Silver Chord*, SY101.

Conditions of MSC Certification

The Certification Report for the Stornoway *Nephrops* fishery outlined four conditions which must be met over the four years following accreditation, two of which will be met by the University of Glasgow. These conditions are described in Table 1 and have been taken from the Certification Report by Moody Marine (Andrews *et al.*).

Table 1: Conditions of the MSC certification to be undertaken by the University of Glasgow

Condition 3 **Cod Bycatch & Discards** Interactions occur between nephrops fisheries and cod populations. Cod is recognised as being in a depleted state and MSC certified fisheries are required to be prosecuted so as to promote rebuilding of depleted target and by-catch species. **Action required:** Measures should be identified and implemented to minimise catches of cod and future catches should be reported in relation to the proportion of cod in nephrops catches, data from previous years and the relative status of the cod stock. Measures should remain in force until cod recovery has been achieved, and further measures adopted to prevent the nephrops fishery from having adverse effects on the recovered stock. **Timescale**: Measures to minimise cod bycatches in the nephrops directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce cod bycatch should be fully implemented within 4 years of certification. **Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3
Condition 4 **Spurdogs** There is a small bycatch of spurdogs in the nephrops fishery. This species is listed on the IUCN Red List as an endangered species. **Action required** Measures should be identified and implemented to minimise bycatch of spurdog. Measures should remain in force until spurdog recovery has been achieved, and further measures adopted to prevent the nephrops fishery from having adverse effects on the recovered stock. **Timescale**: Measures to minimise spurdog bycatches in the nephrops directed fishery should be identified within 2 years of certification. Testing of measures should take place within 3 years of certification. Effective measures to reduce spurdog bycatch should be fully implemented within 4 years of certification. **Relevant Scoring Indicators**: 2.1.4.2, 2.3.1.3

Year 1: Objectives and Progress

The aims and milestone objectives for achieving the conditions of certification were outlined by the University of Glasgow at the beginning of 2009. The aims for year one were as follows:

Condition 3: Cod Bycatch & Discards
Jan 2009 – Jun 2009 • Monitor catches of cod from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). • Investigate length, sex and condition of cod in samples of *Nephrops* catches at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). • Develop YoungsTrace system to provide comprehensive and practical logging of bycatch, including cod. (*Young's Seafood Ltd, Glasgow University)*. **Milestones June 2009** 1. Monitoring programme implemented using current trawling gear. 2. Development of a working traceability system for logging bycatch.
Jul 2009 – Dec 2009 • Install YoungsTrace system on trial vessels for self-assessment of cod bycatch by skippers, and make any necessary modifications after consultation with the skippers (*Young's Seafood Ltd)*. • Continue monitoring catches and length, sex and condition of cod from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). **Milestones December 2009:** 1. Working self-assessment system for monitoring cod bycatch aboard trial vessels. 2. Complete data set of cod bycatch for one year.

Summary of Progress

Between December 2008 and December 2009, a scientific analysis of the bycatch from a commercial *Nephrops* trawler was carried out allowing the proportion of cod in the catches to be analysed over the course of the year. Biometric data have also been collected on all individual cod captured during these surveys.

Due to unforeseen technical issues the YoungsTrace system was not available to begin trials with during 2009, but will be deployed in early 2010.

Analysis is complete from December 2008 to August 2009, and is ongoing for the subsequent months.

Condition 4: Spurdog
Jan 2009 – Jun 2009 • Monitor catches of spurdog from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). • Investigate length, sex and condition of spurdog in samples of *Nephrops* catches at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). • Develop YoungsTrace system to provide comprehensive and practical logging of bycatch, including spurdog (*Young's Seafood Ltd, Glasgow University)*. **Milestones June 2009:** 1. Monitoring programme implemented using current trawling gear. 2. Development of a working traceability system for logging bycatch.
July 2009 – Dec 2009 • Install YoungsTrace system on trial vessels for self-assessment of spurdog bycatch by skippers, and make any necessary modifications after consultation with the skippers (*Young's Seafood Ltd)*. • Continue monitoring catches and length, sex and condition of spurdog from *Nephrops* trawls across the fleet at regular intervals (6-8 weeks) (*Glasgow University, UMBSM*). **Milestones December 2009:** 1. Working self-assessment system for monitoring spurdog bycatch aboard trial vessels. 2. Complete data set of spurdog bycatch for one year.

Summary of Progress

Between December 2008 and December 2009, a scientific analysis of the bycatch from a commercial *Nephrops* trawler was carried out allowing the proportion of spurdog in the catches to be analysed over the course of the year. Biometric and growth data for all spurdog captured during this period are currently being investigated through a student project.

Due to unforeseen technical issues the YoungsTrace system was not available to begin trials with during 2009, but will be deployed in early 2010.

Communication with the Marine Scotland Marine Laboratory (Aberdeen)
Since the beginning of this project, and in line with the recommendations from the MSC certification report, Glasgow University has begun to develop links to scientists in other institutes. To date, these have included:

- A meeting in Aberdeen with their Head of the Inshore Fisheries Department (Dr Anne MacLay) and colleagues to ensure the methods used in the current project are consistent with data collected by Marine Scotland and applicable to the management of the North Minch *Nephrops* stock.

- We have provided preliminary data to Mr Nick Bailey (Marine Scotland) on the percentage of cod appearing in the catches during the beginning of year one with the aim of gaining exemption from the Cod Recovery Plan restrictions for trawlers in the North Minch *Nephrops* fishery. This exemption has recently been achieved (Fishing News, 11th Dec 2009).

- We are in the process of compiling data on whiting abundance from year one to provide to Marine Scotland, at their request, for use in the *Nephrops* assessment for the North Minch area.

Next Steps
The analysis of the data from year one of certification is currently ongoing, and this report should therefore be treated as a preliminary draft until the work can be completed. It is anticipated that this will occur in February 2010.

To complete the objectives set out for year 1, it is imperative that a self-assessment scheme be piloted within the Stornoway trawl fleet as soon as possible in early 2010, and that consultations with the skippers, fishermen and other stakeholders also begin in the near future to allow an effective working relationship to be established between the researchers at Glasgow University and those involved with the fishing industry.

Our intentions for year 2 are to continue monitoring the bycatch aboard the MV *Comrade*, and to begin sampling the bycatch from the rest of the fleet. It is intended to begin this work early in 2010.

Project Summary: Year 1

Study Area

The trawl sites for the initial monitoring work were chosen following discussion with the skipper, and were intended to be as representative of commercial fishing grounds in the area as possible. To this end, the survey trawls were made amongst other vessels in the fleet wherever possible, and the precise locations of each tow were selected by the skipper to ensure data were collected about 'real' commercial catches.

Care was taken to ensure that the sampling regime was scientifically meaningful however, and would allow clear statistical analysis at the end of the programme. Two broad sampling areas were chosen for sampling within the North Minch, one to the south of Stornoway (south site) and one to the south-east (east site).

(a) (b)

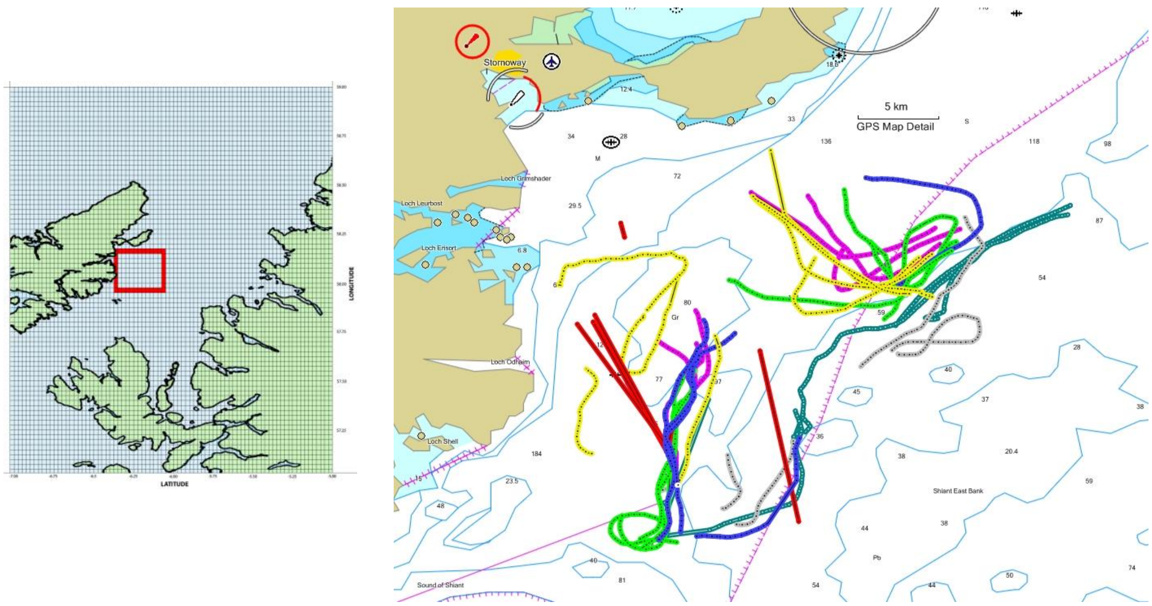


Figure 1: Maps of the study area: (a) The limits of the sampling area are highlighted by the red box and (b) Individual GPS tracks of each tow are shown and colour-coded by month: Red: December 2008; Blue: February 2009; Bright Green: April 2009; Yellow: June 2009; Pink: August 2009; Grey: October 2009; Dark Green: December 2009.

Methodology

Catch Composition

One of the main aims of this project was to determine the amount of bycatch typically captured by the Stornoway *Nephrops* trawler fleet, and the total species composition of the catches. This was done during seven survey trips, carried out over four days every two months between December 2008 and December 2009.

A total of 48 survey trawls of approximately two hours duration were carried out on board the MV '*Comrade*' (SY337, 16.65m, 355kW), a single-rig vessel which was equipped with two different otter trawl nets: a 'disc' net (Fig. 2) and a heavier 'hopper' net (Fig. 3). In order to determine whether the net type had an effect on the overall catch composition, both nets were fished alternately during each sampling trip. Care was taken to ensure that any effects caused by using different gear types could be distinguished from the effects of other factors during analysis of the data.

One or two trawls were made each day, and physical and environmental data were recorded to aid with subsequent analysis of the catches, which were: vessel data (see table 1), trawl date and time, trawl duration, location of each trawl (provisionally divided into 2 sites ('south' and 'east') until there are sufficient data to analyse location more accurately), mean trawl depth (average of start and end depths), net type (light or hopper) and wind direction and speed. Summary data for each trawl is displayed in Table 2. Trawls COM8, COM21 and COM33 were invalid and have not been included in any analysis of catch composition.

Once each catch was recovered on board, the entire animal bycatch was sorted into major groups (roundfish, flatfish, invertebrates and elasmobranches) while the crew sorted the *Nephrops* as they would normally (into graded whole *Nephrops* and tailed *Nephrops*). If a second trawl was made, it would be hauled and sorted in the same manner, and the catches from each haul stored separately until the vessel was back in the harbour.

On return to the harbour, the major groups from each catch were weighed to the nearest 0.1kg and then sorted separately into individual species. All species were recorded and the numbers of individuals per species were counted. The weight of every roundfish and flatfish species was recorded separately, but weights of elasmobranches were pooled into groups ('sharks' and 'rays & skate'), while invertebrates were weighed according to phylum or sub-phylum (Cnidaria, Annelida, Mollusca, Crustacea, Echinodermata, and Ascideacea) due to the low mass of most species.

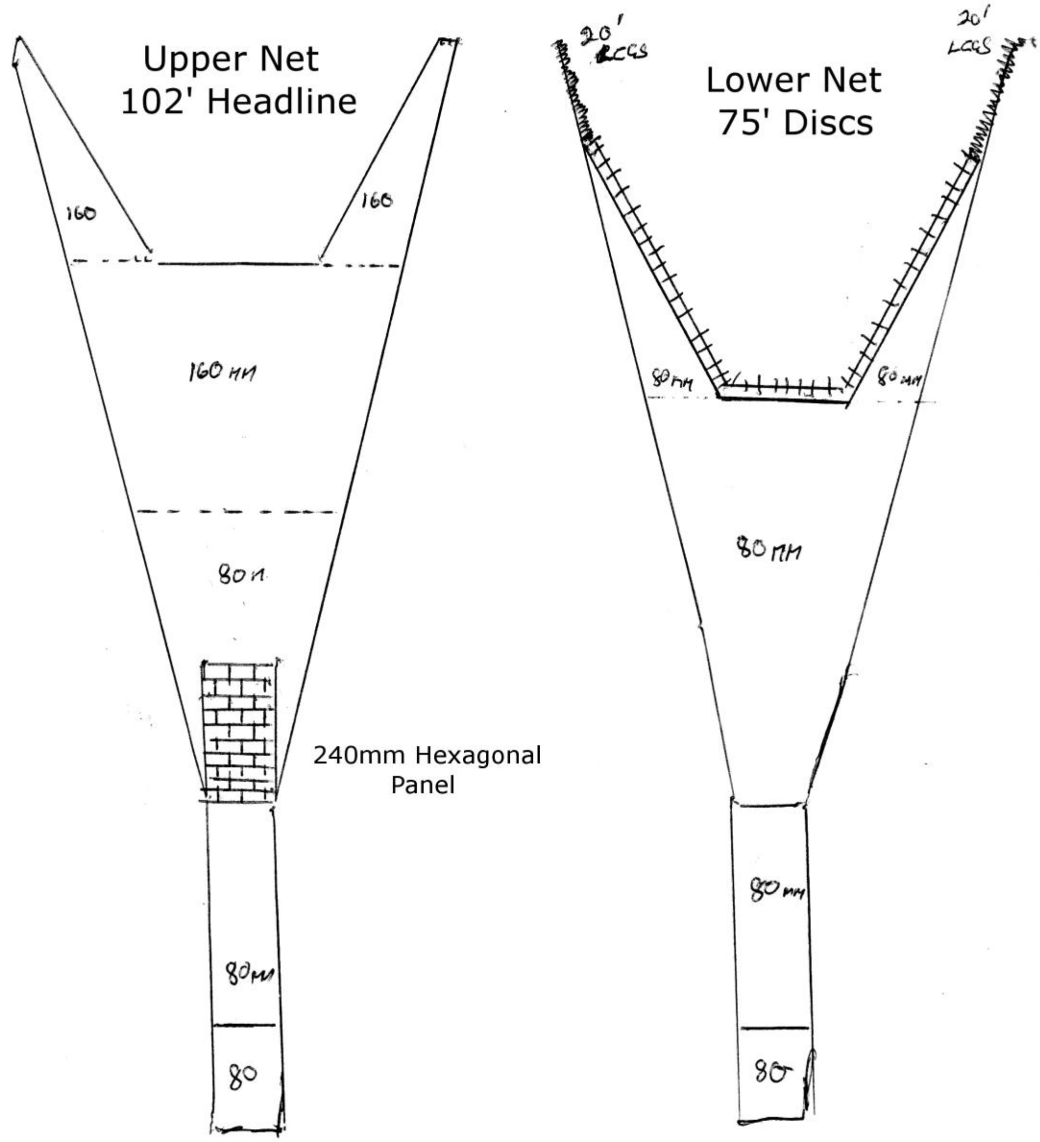


Figure 2: 'Light' trawl net used by *MV Comrade.*

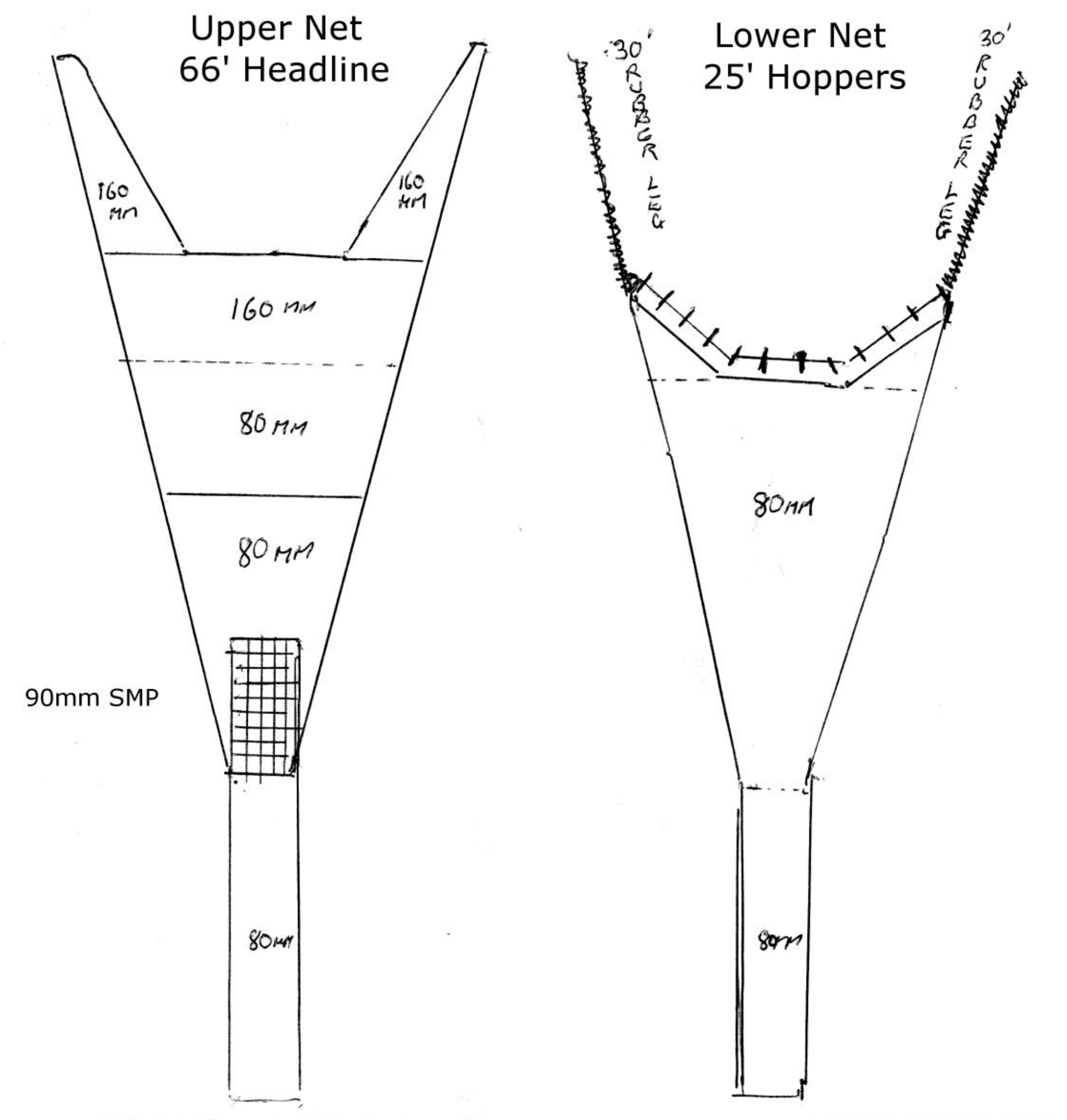


Figure 3: ‘Hopper’ trawl net used by *MV Comrade.*

Table 2: Summary data for each trawl

Trawl ID	Date	Vessel Name	Duration (hours)	Avg Depth (m)	Distance (km)	Speed (km per hour)	Average Speed (knots)	Gear Type	Site	GPS Start	GPS End
COM1	08/12/2008	Comrade	02:25	90				Disc	South	58°07'N 6°18'W	58°07.48'N 6°18.11'W
COM2	09/12/2008	Comrade	02:03	82.5				Hopper	South	58°03.273'N 6°12.542'W	57°57.554'N 6°10.973'W
COM3	10/12/2008	Comrade	02:15	122.5				Hopper	South	58°04.172'N 6°19.294'W	57°59.900'N 6°16.323'W
COM4	10/12/2008	Comrade	02:18	115				Hopper	South	57°59.900'N 6°16.323'W	58°00.086'N 6°16.015'W
COM5	11/12/2008	Comrade	02:18	117.5				Hopper	South	58°04.411'N 6°19.211'W	58°00.160'N 6°16.342'W
COM6	11/12/2008	Comrade	02:10	120				Hopper	South	58°00.160'N 6°16.342'W	58°04.11'N 6°19°9'W
COM7	10/02/2009	Comrade	02:16	107.5	11.7	5.2	2.8	Disc	South	58°02.938'N 6°15.044'W	57°56.944'N 6°16.637'W
COM9	11/02/2009	Comrade	02:00	75	8.8	4.4	2.4	Disc	South	57°57.071'N 6°15.095'W	58°00.348'N 6°10.921'W
COM10	12/02/2009	Comrade	02:00	112.5	8.1	4.1	2.2	Disc	South	58°03.816'N 6°13.551'W	58°00.143'N 6°16.381'W
COM11	12/02/2009	Comrade	02:00	102.5	8.3	4.2	2.2	Hopper	South	58°00.131'N 6°16.376'W	58°06.255'N 6°14.811'W
COM12	13/02/2009	Comrade	02:45	115	11.3	4.1	2.2	Hopper	East	58°08.936'N 6°07.977'W	58°05.425'N 6°06.933'W
COM13	21/04/2009	Comrade	02:05	120	10.2	4.9	2.6	Hopper	South	58°02.616'N 06°15.538'W	57°57.247'N 6°16.258'W
COM14	21/04/2009	Comrade	02:10	140	11	5.1	2.7	Hopper	South	57°56.870'N 6°15.904'W	57°57.762'N 6°18.103'W
COM15	22/04/2009	Comrade	04:30	114.5	16.3	3.6	2.0	Hopper	East	58°06.857'N 6°08.082'W	58°04.285'N 6°17.517'W
COM16	23/04/2009	Comrade	02:15	120.5	10.6	4.7	2.5	Hopper	South	58°01.991'N 6°15.285'W	57°56.680'N 6°17.304'W
COM17	23/04/2009	Comrade	02:15	133.5	11.3	5.0	2.7	Hopper	South	57°56.980'N 6°17.381'W	58°02.595'N 6°15.186'W
COM18	24/04/2009	Comrade	02:00	117.5	10.8	5.4	2.9	Hopper	East	58°08.578'N 6°09.132'W	58°06.822'N 6°04.684'W
COM19	24/04/2009	Comrade	02:05	104.5	11.1	5.3	2.9	Hopper	East	58°06.554'N 6°04.795'W	58°02°595'N 6°15.186'W
COM20	16/06/2009	Comrade	02:19	107	10.3	4.4	2.4	Hopper	South	57°58.765'N 6°15.884'W	58°03.362'N 6°14.186'W
COM21	16/06/2009	Comrade	02:05	147.5	5.3	2.5	1.4	Hopper	South	57°59.818'N 6°19.334'W	58°02.639'N 6°19.562'W
COM22	17/06/2009	Comrade	02:05	123.5	16.3	7.8	4.2	Hopper	East	58°07.836'N 6°11.555'W	58°06.332'N 6°06.104'W
COM23	17/06/2009	Comrade	02:12	117	10.3	4.7	2.5	Hopper	East	58°06.441'N 6°05.593'W	58°06.310'N 6°10.308'W
COM24	18/06/2009	Comrade	02:00	93.5	10.8	5.4	2.9	Hopper	South	58°05.766'N 6°15.821'W	58°04.415'N 6°17.227'W
COM25	18/06/2009	Comrade	02:00	78.5	10.1	5.1	2.7	Hopper	South	58°04.595'N 6°17.096'W	58°05.412'N 6°20.576'W
COM26	19/06/2009	Comrade	02:00	104	11.3	5.7	3.1	Disc	East	58°08.371'N 6°12.852'W	58°05.086'N 6°05.831'W
COM27	19/06/2009	Comrade	02:35	112.5	9.1	3.5	1.9	Hopper	East	58°05.151'N 6°06.509'W	58°08.361'N 6°12.813'W
COM28	11/08/2009	Comrade	02:00	118.5	9.5	4.8	2.6	Disc	East	58°08.376'N 6°10.595'W	58°06.776'N 6°05.265'W
COM29	11/08/2009	Comrade	03:00	116	9	3.6	1.9	Hopper	East	58°07.274'N 6°04.461'W	58°06.615'N 6°09.162'W
COM30	12/08/2009	Comrade	02:00	129	9.1	4.6	2.5	Disc	South	58°03.093'N 6°15.043'W	57°58.640'N 6°16.357'W

Table 2 (cont.)

Trawl ID	Date	Vessel Name	Duration (hours)	Avg Depth (m)	Distance (km)	Speed (km per hour)	Average Speed (knots)	Gear Type	Site	GPS Start	GPS E'Nd
COM31	12/08/2009	Comrade	02:00	110	7.2	3.6	1.9	Hopper	South	58°00.995'N 6°15.934'W	58°04.571'N 6°15.140'W
COM32	13/08/2009	Comrade	02:00	121	9.7	4.9	2.6	Hopper	East	58°08.494'N 6°12.893'W	58°07.315'N 6°05.461'W
COM33	13/08/2009	Comrade	02:00	117.5	9.7	4.9	2.6	Disc	East	58°07.7'N 6°05.3'W	58°07.7'N 6°11.5'W
COM34	14/08/2009	Comrade	02:00	104	9.2	4.6	2.5	Hopper	South	58°03.589'N 6°16.656'W	58°03.569'N 6°16.656'W
COM35	14/08/2009	Comrade	02:05	106	7.2	3.5	1.9	Disc	South	57°59°4'N 6°16°5'W	58°06.571'N 6°15.140'W
COM36	27/10/2009	Comrade	02:00	104	9.26	4.6	2.5	Disc	South	58°03.3'N 6°14.6'W	57°58.5'N 6°13.5'W
COM37	28/10/2009	Comrade	02:00	104	8.7	4.4	2.3	Disc	South	58°02.9'N 6°14.5'W	57°58.2'N 6°14.7'W
COM38	28/10/2009	Comrade	02:10	108.5	8.89	4.1	2.2	Hopper	South	57°58'N 6°14.7'W	58°02.8'N 6°14.8'W
COM39	29/10/2009	Comrade	02:00	107	9.82	4.9	2.7	Disc	East	58°08'N 6°04.6'W	58°02.7'N 6°08.4'W
COM40	29/10/2009	Comrade	02:05	87.5	9.82	4.7	2.5	Hopper	East	58°02.7'N 6°08.'W	58°03.1'N 6°06.8'W
COM41	30/10/2009	Comrade	02:30	98	8.33	3.3	1.8	Disc	South	58°02.4'N 6°14.'W	57°57.9'N 6°14.'W
COM42	30/10/2009	Comrade	01:30	88.5	6.76	4.5	2.4	Hopper	South	57°57.4'N 6°13.4'W	58'N 6°11.2'W
COM43	08/12/2009	Comrade	02:00	102	9.8	4.9	2.6	Disc	South	58°03.9'N 6°11.5'W	58°00.4'N 6°11.1'W
COM44	09/12/2009	Comrade	02:00	97.5	10.7	5.4	2.9	Disc	East	58°04.1'N 6°07. 'W	58°08.'N 6°00.'W
COM45	09/12/2009	Comrade	02:15	94	9.9	4.4	2.4	Hopper	East	58°07.7'N 6°00.'W	58°04.3'N 6°05.7'W
COM46	10/12/2009	Comrade	02:00	118.5	10.7	5.4	2.9	Disc	South	58°01.9'N 6°14.6'W	57°57.9'N 6°14.6'W
COM47	10/12/2009	Comrade	02:00	98.5	9.6	4.8	2.6	Hopper	South	57°57.2'N 6°14.6'W	58°01.2'N 6°11.1'W
COM48	11/12/2009	Comrade	02:30	93.5	13.1	5.2	2.8	Disc	Both	58°5.7'N 6°04.9'W	58°00.5'N 6°10.8'W

Key Species
After the numbers and weights of each species had been recorded, all cod, haddock, whiting and spurdog were stored on ice and frozen. In addition, random subsamples of approximately 100 whole *Nephrops* from each size grade (small, medium or large) and 200 *Nephrops* tails. The discarded *Nephrops* (which included undersize and damaged individuals) were kept and weighed from at least two tows per week and a random subsample was taken.

All samples were stored on ice and frozen at -20ºC by Young's Seafood Ltd. in Stornoway before being transported on ice to the university by haulier approximately one week after capture. The samples were refrozen at -20ºC on arrival at the university and stored until they were required.

Cod, Haddock & Whiting
The samples of fish were allowed to defrost at room temperature for at least 24 hours before analysis. The total length (rounded down to the nearest 5mm) and total weight of each individual fish was recorded, as well as the sex and weight of the viscera and gonads in cod, haddock and whiting. If the total length of an individual fish was less than 15cm, only the total length and weight were recorded. This was due to the very high prevalence of juvenile whiting and haddock in the catches in August and October 2009 and was necessary to reduce the amount of time taken by the analysis. Analysis of these data has been completed for samples taken between December 2008 and August 2009.

Spurdog
The analysis of the spurdog samples is currently being carried out with the assistance of a final-year project student at Glasgow University to allow more thorough data collection and analysis to be carried out on this species. Data from the trials between December 2008 and December 2009 will be available by February 2010.

Nephrops
Samples of *Nephrops* were taken from between one and three hauls per sampling trip to allow biometric measurements to be taken and compared over the course of the year. These data are not presented here as they are not required under the MSC conditions, but are available on request.

Data Analysis

Analysis of the abundance and biomass of bycatch species or groups was carried out using PRIMER 6 software. In order to ensure that trends were accurately identified and analysed, the numbers of each species in each haul and the weights of the major groups per haul were standardised by trawl duration prior to analysis to give numbers and weights per haul per hour respectively. Multivariate analyses were then carried out on both transformed and untransformed data. The untransformed data were examined to determine the gross relationships between the 'real' catches, for which the analyses would give most weighting to the dominant species (including *Nephrops*, which is the most commercially significant species), while more subtle relationships arising as a result of the rarer species could be examined by transforming the data to down-weight the highly dominant species.

Where comparisons between samples were examined, the abundance and biomass data were converted to a similarity matrix using the Bray-Curtis similarity index. The environmental data were normalised, then converted to a similarity matrix using Euclidean distance. The GPS positions were converted to a decimal scale before inclusion in the data set.

Multi-Dimensional Scaling (MDS) and cluster analysis were used to determine the relationships between the bycatch 'communities' from each haul, and BEST and ANOSIM analyses were used to determine the significance of environmental parameters or factors in explaining the differences in these communities. In general, 999 permutations were used for BEST and ANOSIM tests, and MDS analyses were restarted at least 100 times. In each case, significance was taken as $p < 0.05$. To test whether there was a cyclical pattern in the data over the course of the year which may indicate seasonal cycling, an appropriate model matrix was constructed and tested using RELATE analysis.

Results

Species Composition and Broad Trends

After seven survey trips comprising 45 valid trawls, a total of 85 species were recorded, including 24 species of roundfish, 9 species of flatfish, 8 species of elasmobranches, and 45 species of invertebrate. A qualitative summary list of these species is given in Table 3.

The mean proportion of each major group by wet weight is shown in Figure 4. Overall, the landed portion of the *Nephrops* catch comprised the largest component of the catches (63%), with non-target organisms forming the remainder (37%). The *Nephrops* ‘tails’ show the live weight of tailed animals (weight of tails plus weight of cephalothoraces), and ‘discarded’ *Nephrops* therefore only included discarded whole animals (undersize and damaged individuals).

On average over the entire sampling period, the five main groups making up the majority of the catches were *Nephrops* (36.98 kg/hour), ‘sharks’ (5.87 kg/hour), *Trisopterus* spp. (3.97 kg/hour), whiting (2.45kg/hour) and other Crustacea (1.58kg/hour). Numerically the main species were similar, and included *Nephrops* (1287 per hour), *Trisopterus* spp. (251 per hour), *Pandalus borealis* (137 per hour), whiting (59 per hour) and *Munida rugosa* (15.9 per hour).

Table 3: List of species recorded from 45 trawls between December 2008 and December 2009

Species Name	
ROUNDFISH	**INVERTEBRATES**
Agonus cataphractus (Linnaeus, 1758)	*Funiculina quadrangularis (Pallas, 1766)*
Aspitrigla cuculus (Linnaeus, 1758)	*Pennatula phosphorea Linnaeus, 1758*
Callionymus lyra Linnaeus 1758	*Actinauge richardi* (Marion, 1882)
Capros aper (Linnaeus, 1758)	*Urticina* sp.
Clupea harengus Linnaeus 1758	*Adamsia carciniopados* (Otto, 1823)
Enchelyopus cimbrius (Linnaeus, 1766)	(Solitary coral)
Gadus morhua Linnaeus 1758	*Cyanea capillata* (Linnaeus, 1758)
Gaidropsarus vulgaris (Cloquet, 1824)	*Cyanea lamarcki Péron and Lesueur, 1809*
Lophius piscatorius Linnaeus, 1758	*Aurelia aurita (Linnaeus, 1758)*
Melanogrammus aeglefinus (Linnaeus 1758)	*Alcyonium digitatum Linnaeus, 1758*
Merlangius merlangus (Linnaeus 1758)	*Aequipecten opercularis (Linnaeus, 1758)*
Merluccius merluccius (Linnaeus 1758)	*Arctica islandica (Linnaeus, 1767)*
Micromesistius poutassou (Risso, 1827)	*Loligo vulgaris* Lamarck, 1798
Molva molva (Linnaeus, 1758)	*Eledone cirrhosa* Lamarck, 1798
Phycis blennoides (Brünnich, 1768)	*Family Sepiolidae*
Pollachius virens (Linnaeus, 1758)	*Nudibranch sp. 1*
Scomber scombrus Linnaeus, 1758	*Scaphander lignarius (Linnaeus, 1767)*
Trachurus trachurus (Linnaeus, 1758)	*Aporrhais pespelicanis Linnaeus, 1758*
Family Triglidae	*Neptunea antiqua (Linnaeus, 1758)*
Trisopterus spp.	*Aphrodita aculeata Linnaeus, 1761*
Zeus faber Linnaeus, 1758	*Palinurus elphas (Fabricius, 1787)*
Alosa alosa (Linnaeus, 1758)	*Munida rugosa Fabricius, 1775*
Conger conger (Linnaeus, 1758)	*Pagurus prideaux Leach, 1815*
Labrus bimaculatus Linnaeus, 1758	*Pagurus bernhardus Linnaeus, 1758*
	Cancer pagurus Linnaeus, 1758
FLATFISH	*Liocarcinus depurator (Linnaeus, 1758)*
Buglossidium luteum (Risso, 1810)	*Macropipus tuberculatus (Roux, 1830)*
Glyptocephalus cynoglossus (Linnaeus, 1758)	*Goneplax rhomboides (Linnaeus, 1758)*
Hippoglossoides platessoides (Fabricius 1790)	*Atelecyclus rotundatus (Olivi, 1792)*
Hippoglossus hippoglossus (Linnaeus, 1758)	*Family Magidae*
Lepidorhombus whiffiagonis (Walbaum, 1792)	*Crangon crangon (Linnaeus, 1758)*
Limanda limanda (Linnaeus, 1758)	*Pandalus borealis* Kroyer,1838
Microstomus kitt (Walbaum, 1792)	*Pasiphaea sivado (Risso, 1816)*
Pleuronectes platessa Linnaeus, 1758	(Shrimp sp. 1)
Scophthalmus rhombus (Linnaeus, 1758)	*Asterias rubens* Linnaeus, 1758
	Luidia ciliaris (Philippi, 1837)
ELASMOBRANCHS	*Marthasterias glacialis (Linnaeus, 1758)*
Dipturus oxyrinchus (Linnaeus, 1758)	*Porania* sp.
Galeus melastomus Rafinesque, 1810	*Ophiura ophiura (Linnaeus, 1758)*
Leucoraja naevus (Müller & Henle, 1841)	(Basket star)
Raja clavata Linnaeus, 1758	*Parastichopus tremulus (Gunnerus, 1767)*
Raja brachyura Lafont, 1873	*Echinus* sp.
Raja montagui Fowler, 1910	*Brissopsis lyrifera*
Scyliorhinus canicula (Linnaeus, 1758)	Tunicata sp1
Squalus acanthias Linnaeus, 1758	

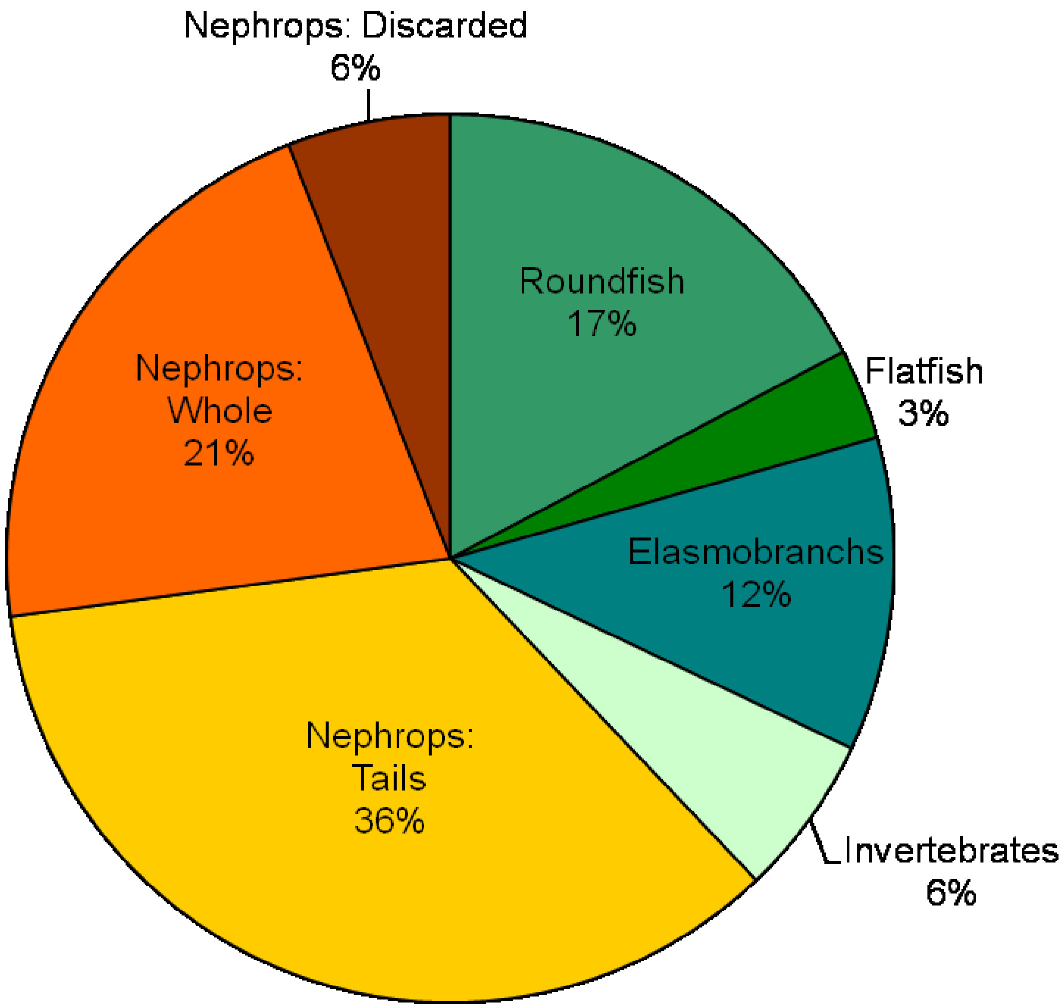


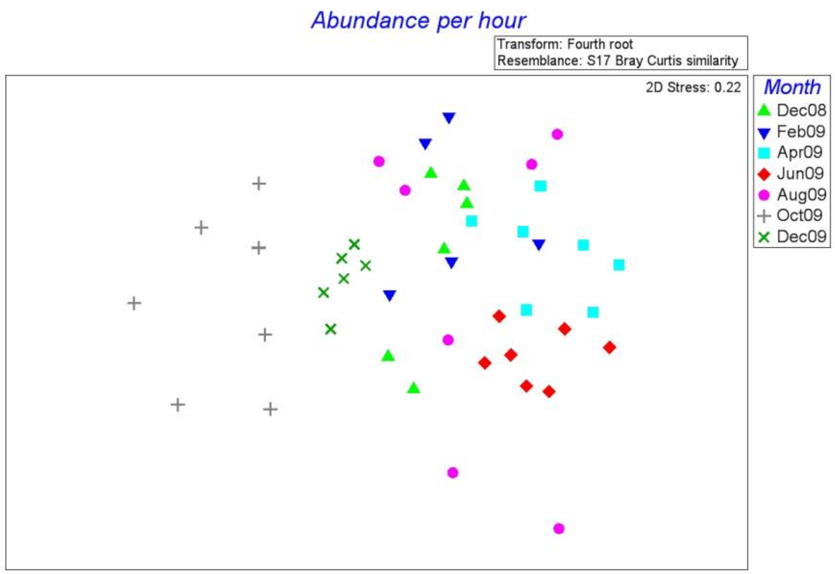
Figure 4: Mean overall catch composition from all valid trawls made between December 2008 and December 2009.

Intra-Annual Variation

ANOSIM analysis of catch composition throughout the sampling period suggested that there was a significant effect of sampling month on both abundance and biomass data ($p < 0.001$) regardless of the transformation applied. Total catch weight was also found to be a significant predictor of the relationships between the catches ($p < 0.001$), but only for untransformed abundance and biomass data. No other factors were found to be significant. The relationships between the catches are shown for abundance and biomass data as MDS plots in Figure 5.

To test whether there was a cyclical (i.e. seasonal) effect over the course of the year, a model matrix was constructed and tested against the abundance data using RELATE analysis. This analysis showed a significant cyclical pattern in the abundance and biomass data, regardless of the transformation applied, although the test statistic was quite low in all cases suggesting that seasonal differences alone are insufficient to explain the variation in the data. Resemblance matrices based on SIMPER analysis were constructed to show the mean monthly pattern in the data and is presented as an MDS plot in Figure 6.

(a)



(b)

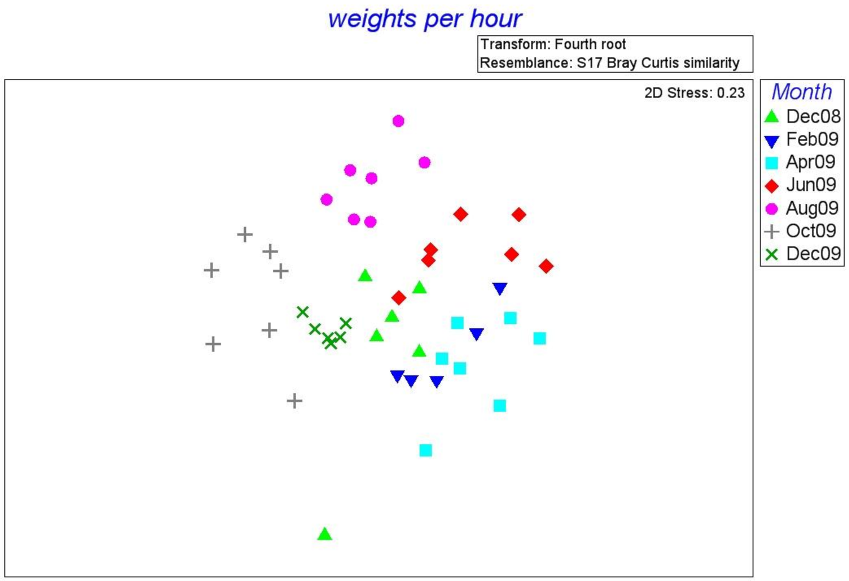


Figure 5: MDS plots showing the relationships between catches over the sampling period for (a) abundance data (4th root transformed) and (b) biomass data (4th root transformed). The sampling month is indicated by the coloured markers and some clustering of data points by month is apparent.

(a) (b)

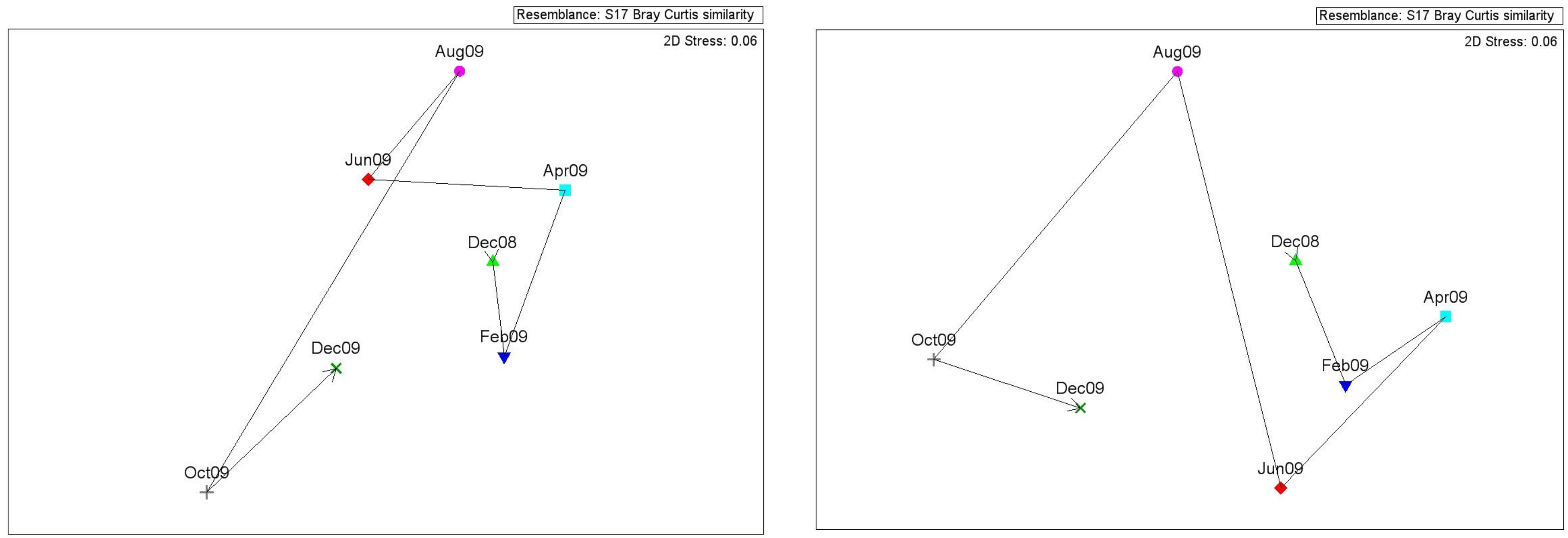


Figure 6: MDS plot showing the mean similarities between months for (a) abundance data (4th root transformed) and (b) biomass data (4th root transformed). The trajectory is marked to show the progression through the year.

Differences between months were also found between the mean numbers and weights of bycatch captured per hour of fishing. Figure 7 shows the mean proportion of the major bycatch groups per month in weight captured per hour. Univariate analysis of these data was carried out in PRIMER using the GLM (general linear model) function, and one-way ANOVAs with a *post-hoc* Tukey test to determine where any significant differences were occurring. Catch weights per hour were found to vary between the sampling months for all major groups ($p > 0.05$), with the exception of the elasmobranchs. Similar differences were also found in the abundance data.

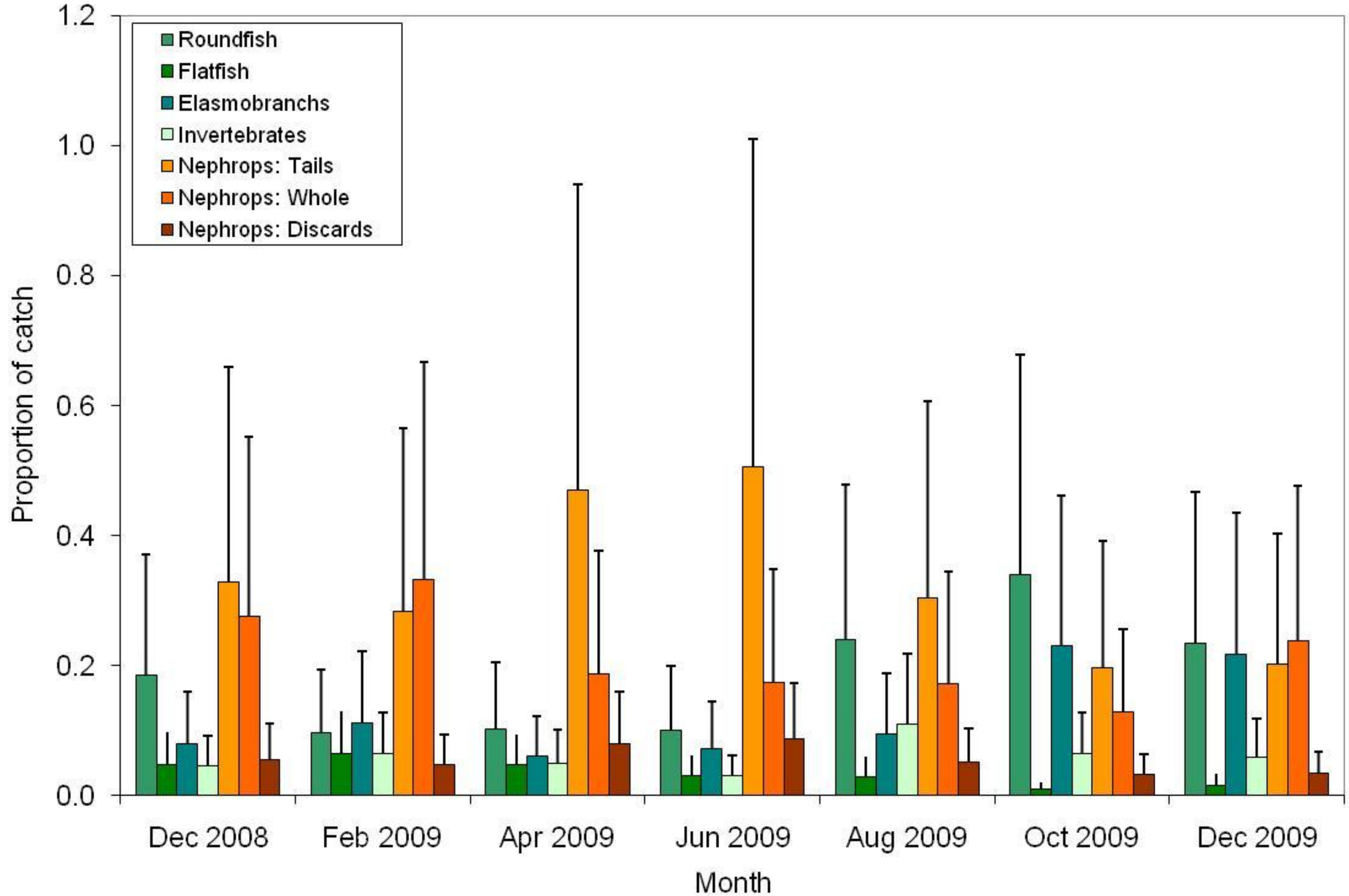


Figure 7: Mean proportion of each component of the catches by wet weight from each sampling trip. 'Nephrops: tails' shows the live weight of the tailed animals. Error bars show one standard deviation.

Key Species

Cod, Haddock and Whiting

A total of 24 cod, 116 haddock and 1813 whiting were collected and analysed (from a total of 30, 116 and 2085 captured respectively) from the 34 trawls between December 2008 and August 2009. The length-weight curves for each species is presented in Figures 8, 9 and 10, with fitted trend line (with equation and R^2 values) and the minimum landing size (MLS) indicated in each case. The total percentage of cod occurring in each catch (by wet weight) is shown in Figure 11.

The mean lengths, CI, SCF, GSI and maturity class of the sampled fish are shown in Table 4 for each month. It should be remembered however, that these values are often based on relatively few individuals (especially GSI, where gonad weight was not always available) and care should therefore be taken when interpreting the data.

Table 4: Mean lengths, condition and maturity data for cod, haddock and whiting between December 2008 and August 2009.

Month	Species	N	Mean Length (cm)	K	SCF	GSI
December	Cod	4	42.75	1.14	1.04	0.012
	Haddock	6	31.58	0.95	0.84	0.013
	Whiting	21	29.55	0.76	0.73	0.01
February	Cod	9	26.61	1.03	0.95	0.049
	Haddock	11	34.68	0.95	0.83	0.046
	Whiting	8	27.50	0.84	0.73	0.03
April	Cod	3	36.00	0.95	0.86	0.006
	Haddock	17	34.85	0.80	0.70	0.019
	Whiting	4	29.50	0.64	0.56	0.02
June	Cod	5	45.67	1.07	0.96	0.005
	Haddock	8	33.71	0.94	0.82	0.003
	Whiting	193	28.64	0.72	0.66	0.01
August	Cod	3	36.67	1.11	1.01	0.00
	Haddock	74	12.17	0.83	0.86	0.00
	Whiting	1587	11.20	0.70	0.67	0.00

The lengths of haddock and whiting were both significantly lower in August than in any other month (Kruskal-Wallis test: $p > 0.001$), with very large numbers of individuals appearing in the catches. This is suggestive of strong recruitment of whiting in this region following spawning earlier in the year, however analysis is ongoing and such conclusions must be viewed with caution until it is complete.

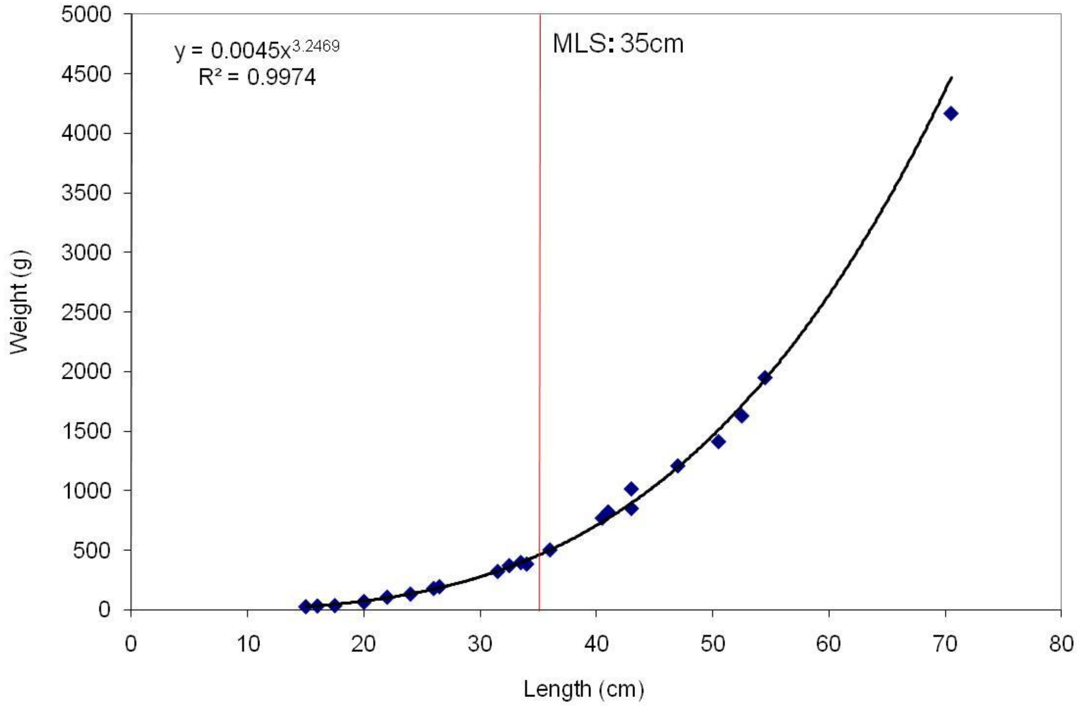


Figure 8: Length-weight relationship for sampled Atlantic cod. MLS (35cm) is indicated by the red bar. $R^2 = 0.9974$.

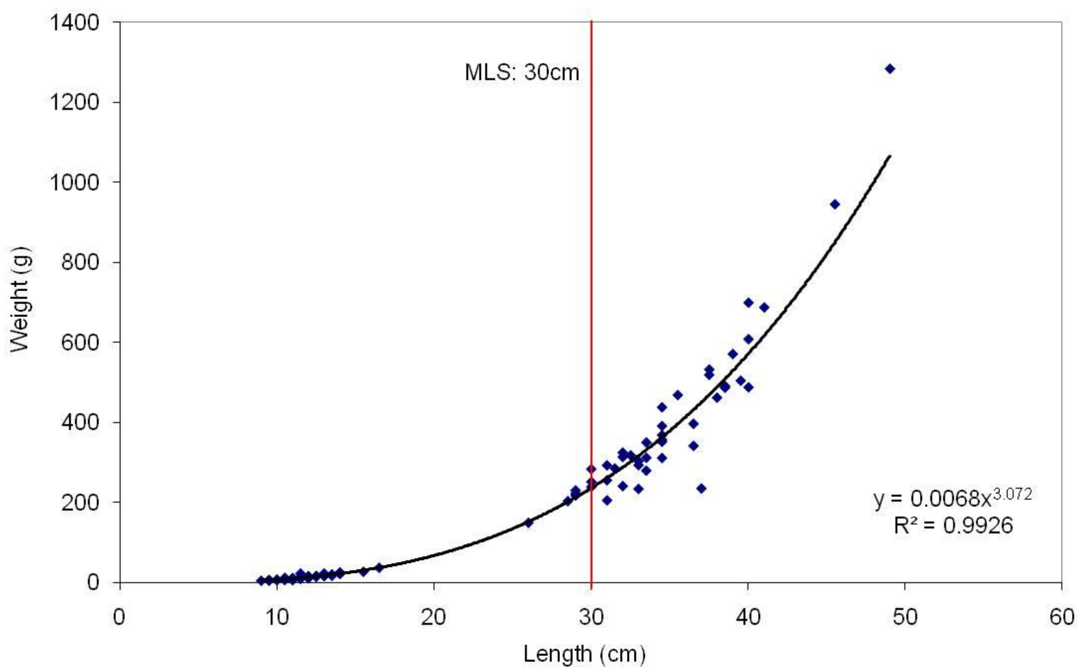


Figure 9: Length-weight relationship for sampled haddock. MLS (30cm) is indicated by the red bar. $R^2 = 0.9926$.

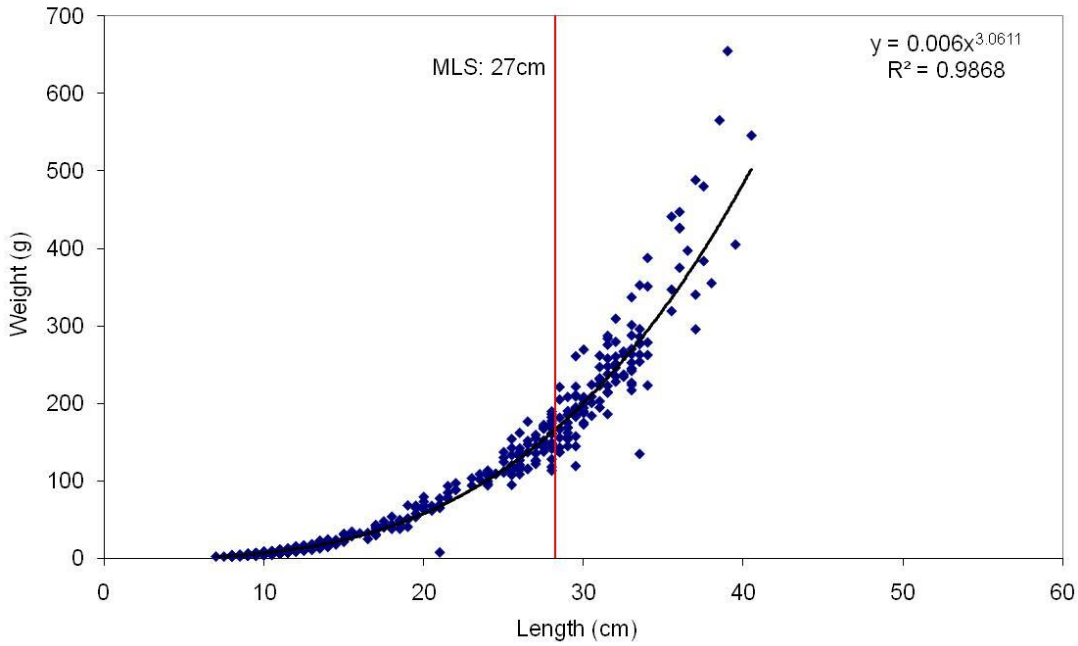


Figure 10: Length-weight relationship for sampled whiting. MLS (27cm) is indicated by the red bar. R^2 = 0.9868.

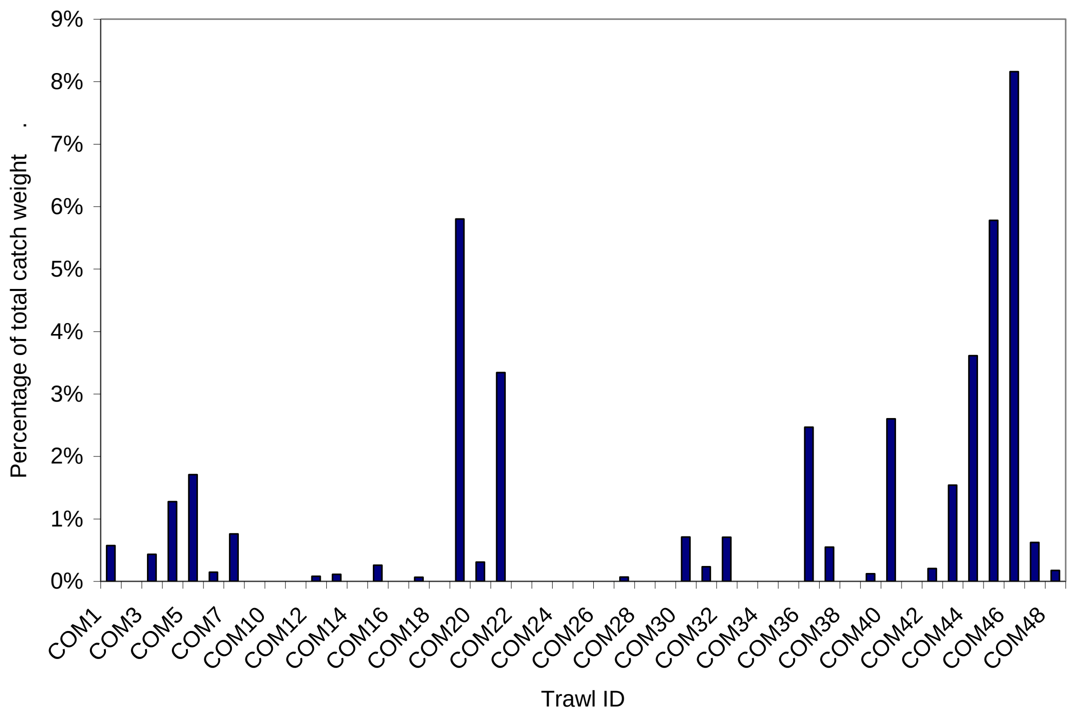


Figure 11: Percentage of cod by wet weight captured in each trawl between December 2008 and December 2009.

Spurdog
A total of 105 spurdog were captured between December 2008 and December 2009, but these data are currently being analysed as part of a student project and will not be available for reporting until February 2010. The total numbers of spurdog per catch are shown in Figure 12.

None of the captured spurdog appeared to cope well with the trawling process, and were generally moribund or showing only slight movement after sorting, along with evidence of bleeding and possible internal injury. These injuries were not documented, but along with anecdotal evidence from the fishermen, they suggest that survival rates of this species may be low after capture in trawling gear.

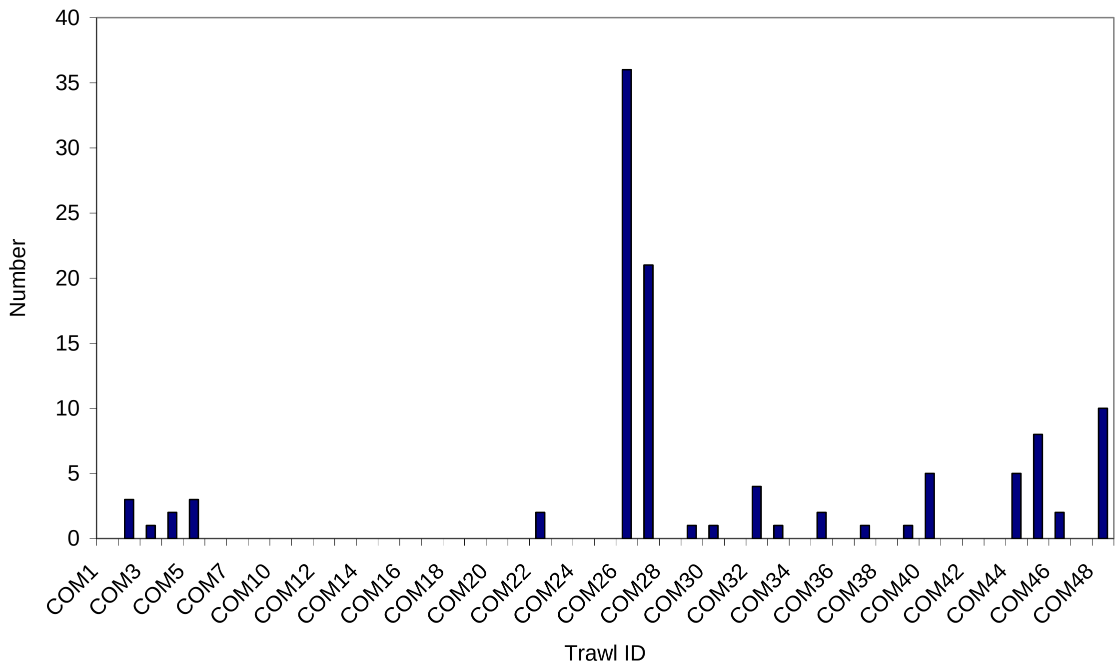


Figure 12: Number of spurdog captured in each trawl between December 2008 and December 2009.